

# HYDROMODIFICATION SCREENING FOR QUARRY CREEK

(C.T. 11-04)

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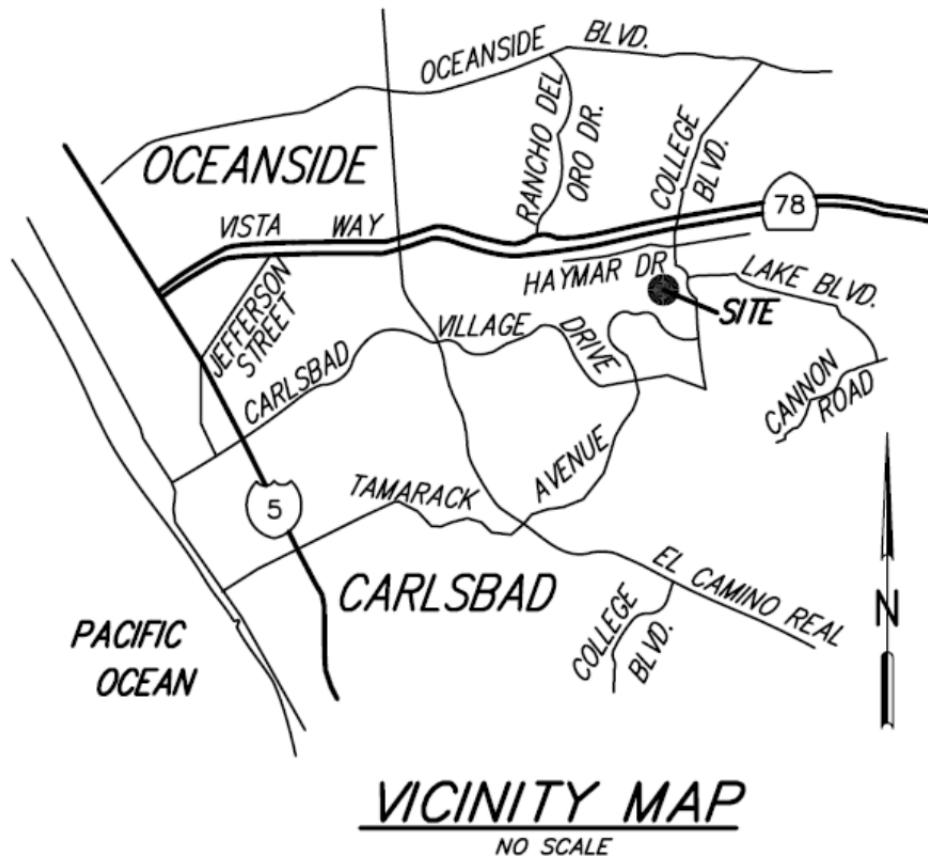
- A. SCCWRP Initial Desktop Analysis
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## **MAP POCKET**

Study Area Exhibit

## INTRODUCTION

The County of San Diego's March 2011, *Final Hydromodification Management Plan*, and January 8, 2011, *Standard Urban Stormwater Mitigation Plan* (SUSMP) outline low flow thresholds for hydromodification analyses. The thresholds are based on a percentage of the pre-project 2-year flow ( $Q_2$ ), i.e.,  $0.1Q_2$  (low),  $0.3Q_2$  (medium), or  $0.5Q_2$  (high). A threshold of  $0.1Q_2$  represents a downstream receiving conveyance system with a high susceptibility to erosion. This is the default value used for hydromodification analyses and will result in the most conservative (greatest) on-site facility sizing. A threshold of  $0.3Q_2$  or  $0.5Q_2$  represents downstream receiving conveyance systems with a medium or low susceptibility to erosion, respectively. In order to qualify for a medium or low susceptibility rating, a project must perform a channel screening analysis based on a "hydromodification screening tool" procedure developed by the Southern California Coastal Water Research Project (SCCWRP). The SCCWRP results are compared with the critical shear stress calculator results from the County of San Diego's BMP Sizing Calculator to establish the appropriate susceptibility threshold of low, medium, or high.



### Vicinity Map

This report provides hydromodification screening analyses for McMillin Land Development's (McMillin) Quarry Creek project (C.T. 11-04) being designed by Project Design Consultants (PDC). The project is located south of Haymar Drive and west of College Boulevard in the cities of Carlsbad and Oceanside, California (see the Vicinity Map above as well as the Study Area Exhibit in the map pocket). A portion of the project will be within Hanson Aggregates Pacific

Southwest Inc.'s (Hanson) South Coast Materials Quarry. Reclamation of the Hanson site was recently approved by the Cities of Carlsbad (SUP 07-03 and Drawing No. 470-5A) and Oceanside (RMA-1-2001 Revision 05 and Drawing No. G11-0002). The McMillin project will not proceed until Hanson's reclamation grading is complete. Hanson's reclamation grading will result in channelization of Buena Vista Creek within their site. The channelization will create a vegetated trapezoidal channel with a 150-foot bottom width, 2.5 to 1 side slopes, a terrace along each channel bank, and seven riprap drop structures. The pre-reclamation longitudinal channel slope was hydraulically steep, which resulted in erosive flow velocities. In order to reduce the 100-year flow velocities below the non-erosive threshold of 6 feet per second (fps) as much as possible, the seven drop structures were used to reduce the longitudinal slope. This resulted in a hydraulically stable channel. Since the drop structures and channel were designed to be stable in accordance with established engineering criteria, long-term stability can be assumed for the purposes of this report. The drop structures and channel construction was complete in September 2012.

Surface runoff from McMillin's proposed project and tributary off-site areas will be collected by a series of on-site storm drain systems (see Study Area Exhibit). The storm drain systems will have eight discharge locations. Five of the discharge locations will be directly into the Buena Vista Creek channel being constructed by the Hanson project (into Reaches 5 and 6 on the Study Area Exhibit). Buena Vista Creek flows in a westerly direction and bisects the easterly portion of the site. The sixth storm drain discharge location will be into an existing minor, natural drainage course approximately mid-way along the southerly development area (into Reach 7 on the Study Area Exhibit). This drainage course will be referred to herein as the Middle Tributary and flows a short distance to the north and confluent into Buena Vista Creek. The final two discharge locations will be into an unnamed natural tributary canyon to Buena Vista Creek (into Reach 8 on the Study Area Exhibit). The canyon is just beyond the westerly edge of the southerly development area and flows in a northwesterly direction into Buena Vista Creek. This tributary will be identified herein as the West Tributary.

The SCCWRP screening tool requires both office and field work to establish the vertical and lateral susceptibility of a downstream receiving channel to erosion. The vertical and lateral assessments are performed independently of each other although the lateral results can be affected by the vertical rating. A screening analysis was performed to assess the low flow threshold for each point of compliance. A point of compliance exists at the project's storm drain outlets. Each point of compliance establishes a location for which a channel screening analysis must be performed.

The initial step in performing the SCCWRP screening analysis is to establish the domain of analysis and the study reaches within the domain. This is followed by office and field components of the screening tool along with the associated analyses and results. The following sections cover these procedures in sequence.

## DOMAIN OF ANALYSIS

SCCWRP defines an upstream and downstream domain of analysis, which establish the required study limits. The Quarry Creek project discharges into three watercourses: Buena Vista Creek, the minor drainage course near the middle of the southerly development area (Middle Tributary), and the unnamed tributary canyon just west of the southerly development area (West Tributary). Separate upstream and downstream domain of analyses must be established within each of these three watercourses. The County of San Diego's HMP specifies the downstream domain of analysis based on the SCCWRP criteria. The HMP indicates that the downstream domain is the **first point** where one of these is reached:

- at least one reach downstream of the first grade control point
- tidal backwater/lentic waterbody
- equal order tributary
- accumulation of 50 percent drainage area for stream systems or 100 percent drainage area for urban conveyance systems (storm drains, hardened channels, etc.)

The upstream limit is defined as:

- proceed upstream for 20 channel top widths or to the first grade control point, whichever comes first. Identify hard points that can check headward migration and evidence of active headcutting.

SCCWRP defines the maximum spatial unit, or reach (a reach is circa 20 channel widths), for assigning a susceptibility rating within the domain of analysis to be 200 meters (656 feet). If the domain of analysis is greater than 200 meters, the study area should be subdivided into smaller reaches of less than 200 meters for analysis. Most of the units in the HMP's SCCWRP analysis are metric. Metric units are used in this report only where given so in the HMP. Otherwise English units are used.

### Downstream Domain of Analysis

A separate downstream domain of analysis for the three watercourses (Buena Vista Creek, Middle Tributary, and West Tributary) in the study area has been determined by assessing and comparing the four bullet items above for each point of compliance (i.e., the storm drain discharge locations). There are five discharge locations directly into Buena Vista Creek (see the Study Area Exhibit). The easterly-most is identified on the Study Area Exhibit as point of compliance 1 (POC 1). The middle two discharge locations are at essentially the same point along the creek, so these are identified as POC 2. Similarly, the westerly two discharge locations are at essentially the same point along the creek and are identified as POC 3. The storm drain discharge location into the Middle Tributary is POC 4. There are two storm drain discharge locations into the West Tributary. The discharge locations are in proximity to each other and the physical and vegetative conditions in the West Tributary are similar, so both discharge locations were considered to be POC 5.

Per the first bullet item above, the first permanent grade control below POC 1 and 2 will be the closest downstream riprap drop structure within Buena Vista Creek constructed by the Hanson

project. For POC 1 and 2, a drop structure exists within 70 feet. For POC 3, 4, and 5 the first permanent grade control is a concrete-lined trapezoidal channel approximately 250 feet upstream of El Camino Real (see Study Area Exhibit).

The second bullet item is the tidal backwater or lentic (standing or still water such as ponds, pools, marshes, lakes, etc.) waterbody location. The closest waterbody that meets this criteria is Buena Vista Lagoon. Buena Vista Lagoon is downstream of all the permanent grade controls, so the second bullet item will not govern.

The final two bullet items are related to the tributary drainage area. According to a June 23, 1994, *Hydrologic Study for Buena Vista Creek Basin*, by Hunsaker & Associates San Diego, Inc. the Buena Vista Creek tributary drainage areas at College Boulevard, El Camino Real, and the Pacific Ocean are 13.35, 17.33, 21.55 square miles, respectively (see Appendix A). POC 1 through 3 outlet into Buena Vista Creek between College Boulevard and El Camino Real. Based on the Hunsaker areas, the 50 percent or equal order (100 percent) tributary will not govern for POC 1 through 3 because they occur in the Pacific Ocean. The project hydrology study by PDC shows that the tributary area to POC 4 is 107.4 acres (see Appendix A). Based on this, an equal order tributary below POC 4 exists where the Middle Tributary confluent with Buena Vista Creek since the Buena Vista Creek watershed is much larger than the POC watershed. In addition, a drainage basin delineation determined that the tributary area to the West Tributary is 0.48 square miles (see the Watershed Delineation exhibit in Appendix A). From this, an equal area tributary below POC 5 exists where the West Tributary confluent with Buena Vista Creek.

Based on the above information, the following are the downstream domain of analysis locations for POC 1 through 5. For POC 1 and 2, the downstream domain of analysis location is one reach (200 meters) below the nearest downstream drop structure constructed by the Hanson project. This location will be within Hanson's Buena Vista Creek channel. For POC 3, the downstream domain of analysis location is one reach below the upstream end of the concrete trapezoidal channel near El Camino Real. This location will land within the concrete channel because the channel is longer than a reach. For POC 4, the downstream domain of analysis location is where the Middle Tributary confluent with Buena Vista Creek. For POC 5, the downstream domain of analysis location is where the West Tributary confluent with Buena Vista Creek.

#### Upstream Domain of Analysis

For POC 1 through 3, a permanent drop structure (or grade control) exists immediately upstream of each storm drain discharge point. Therefore, the adjacent drop structure establishes the upstream domain of analysis location for POC 1 through 3. For POC 4, the Middle Tributary does not extend upstream of POC 4, so the upstream domain of analysis location will be at POC 4. For POC 5, a grade control does not exist upstream of the storm drain outlets. Therefore, the upstream domain of analysis location is based on 20 channel top widths upstream of the upper storm drain outlet. The average top width upstream of POC 5 is approximately 20 feet from the topographic mapping, so the upstream domain of analysis location is 400 feet upstream of the upper pipe outlet.

### Study Reaches within Domain of Analysis

The Buena Vista Creek and West Tributary domain of analysis extend over relatively long distances. The entire domain of analysis along Buena Vista Creek covers over 9,000 feet, while the entire domain of analysis along the West Tributary covers over 3,200 feet. The domain of analysis for these two streams was subdivided into study reaches with similar characteristics (see Study Area Exhibit). Buena Vista Creek contains six study reaches (Reach 1 through 6) and the West Tributary contains two study reaches (Reach 8 and 9).

Each study reach other than 5, 7, and 9 is longer than the 656 feet maximum reach length specified by SCCWRP. Review of topographic mapping, aerial photographs, and field conditions reveals that the physical (channel geometry and longitudinal slope), vegetative, hydraulic, and soil conditions within each longer reach are relatively uniform. Subdividing the reaches into smaller subreaches of less than 656 feet will not yield significantly varying results within a reach. Although the screening tool was applied across the entire length of each reach, the results will be similar for shorter subreaches within each reach.

## **INITIAL DESKTOP ANALYSIS**

After the domain of analysis is established, SCCWRP requires an “initial desktop analysis” that involves office work. The initial desktop analysis establishes the watershed area, mean annual precipitation, valley slope, and valley width. These terms are defined in Form 1, which is included in Appendix A. SCCWRP recommends the use of National Elevation Data (NED) to determine the watershed area, valley slope, and valley width. The NED data is similar to USGS mapping. Therefore, USGS quadrangle mapping was used to establish the watershed area, where needed. For this report, 2-foot contour interval topographic mapping by PDC was available covering the entire study reaches of Buena Vista Creek, the Middle Tributary, and the West Tributary. The PDC mapping is more detailed than NED/USGS topography, so it was used to determine the valley slope and valley width.

The watershed areas tributary to Buena Vista Creek, the Middle Tributary, and the West Tributary were determined from different sources. For Buena Vista Creek, the June 23, 1994, *Hydrologic Study for Buena Vista Creek Basin*, by Hunsaker & Associates San Diego, Inc. provides tributary watershed areas at College Boulevard and El Camino Real (see Appendix A), which bracket the upstream and downstream ends of the study area, respectively. The watershed areas are 17.33 and 13.35 square miles, respectively. The tributary areas to Reaches 1 through 6 were determined by interpolating the Hunsaker values based on the location of the downstream end of each reach between College Boulevard and El Camino Real. Table 1 summarizes the tributary areas.

For the Middle Tributary, the watershed area (107.4 acres or 0.17 square miles) was obtained from PDC’s hydrologic analysis (see PDCs work map in Appendix A). This represents the post-project area that will drain to the Middle Tributary. For the West Tributary, the watershed area extends over a relatively large area. Consequently, the USGS mapping was used to delineate the area in accordance with SCCWRP. A “Watershed Delineation” exhibit is included in the Appendix A and shows the drainage areas tributary to Reach 8 and 9 in the West Tributary.

The mean annual precipitation was obtained from the County of San Diego's BMP Sizing Calculator and is 13.3 inches (see Appendix A).

The valley slopes of Reaches 1 through 9 were determined from the PDC's 2-foot contour interval topographic mapping. The valley slope is the longitudinal slope of the channel bed along the flow line, so it is determined by dividing the elevation difference within a reach by the flow path.

The valley width is the bottom width of the stream channel. The average valley width within each reach was estimated from PDC's topographic mapping, field observations, and review of aerial photographs. The average valley slope and valley width for each reach are summarized in Table 1.

<b>Reach</b>	<b>Tributary Area, sq. mi.</b>	<b>Valley Slope, m/m</b>	<b>Valley Width, m</b>
1	17.33	0.0067	30.5
2	16.75	0.0022	7.0
3	16.43	0.0074	15.0
4	14.91	0.0071	10.0
5	14.50	0.0076	5.0
6	14.28	0.0014	45.0
7	0.17	0.0659	2.5
8	0.48	0.0156	18.0
9	0.32	0.0138	3.0

**Table 1. Summary of Valley Slope and Valley Width**

The Table 1 values were input to a spreadsheet to calculate the simulated peak flow, screening index, and valley width index outlined in Form 1. The input data and results are tabulated in Appendix A. This completes the initial desktop analysis.

## **FIELD SCREENING**

After the initial desktop analysis is complete, a field assessment must be performed. The field assessment is used to establish a natural channel's vertical and lateral susceptibility to erosion. SCCWRP states that although they are admittedly linked, vertical and lateral susceptibility are assessed separately for several reasons. First, vertical and lateral responses are primarily controlled by different types of resistance, which, when assessed separately, may improve ease of use and lead to increased repeatability compared to an integrated, cross-dimensional assessment. Second, the mechanistic differences between vertical and lateral responses point to different modeling tools and potentially different management strategies. Having separate

screening ratings may better direct users and managers to the most appropriate tools for subsequent analyses.

The field screening tool uses combinations of decision trees and checklists. Decision trees are typically used when a question can be answered fairly definitively and/or quantitatively (e.g.,  $d_{50} < 16$  mm). Checklists are used where answers are relatively qualitative (e.g., the condition of a grade control). Low, medium, high, and very high ratings are applied separately to the vertical and lateral analyses. When the vertical and lateral analyses return divergent values, the most conservative value shall be selected as the flow threshold for the hydromodification analyses.

### Vertical Stability

The purpose of the vertical stability decision tree (Figure 6-4 in the County of San Diego HMP) is to assess the state of the channel bed with a particular focus on the risk of incision (i.e., down cutting). The decision tree is included in Figure 28. The first step is to assess the channel bed resistance. There are three categories defined as follows:

1. Labile Bed – sand-dominated bed, little resistant substrate.
2. Transitional/Intermediate Bed – bed typically characterized by gravel/small cobble, Intermediate level of resistance of the substrate and uncertain potential for armoring.
3. Threshold Bed (Coarse/Armored Bed) – armored with large cobbles or larger bed material or highly-resistant bed substrate (i.e., bedrock).

Figures 21 through 27 show photographs of the bed material within Buena Vista Creek, the Middle Tributary, and the West Tributary. A gravelometer is included in the photographs for reference. Each square on the gravelometer indicates grain size in millimeters (the squares range from 2 mm to 180 mm). Based on the photographs and site investigation, the bed material and resistance is generally within the transitional/intermediate bed category. There was no evidence of a threshold bed condition. The figures show that the grain size is fairly large in the upstream reach of Buena Vista Creek and decreases in the downstream direction. Even the smaller grain sizes are rather gravelly. In the Middle Tributary, the grain size is typically in the gravel range. In the West Tributary, there are gravel sized particles, but a larger population of smaller grain sizes.

The figures show dense vegetation throughout the natural portion of Buena Vista Creek and the West Tributary. The vegetation consists of a variety of mature grasses, shrubs, and trees. Vegetation prevents bed incision because its root structure binds soil and because the aboveground vegetative growth will reduce flow velocities. Table 5-13 from the County of San Diego's *Drainage Design Manual* outlines maximum permissible velocities for various channel linings (Table 5-13 is included in Appendix B). Maximum permissible velocity is defined in the manual as the velocity below which a channel section will remain stable, i.e., not erode. Table 5-13 indicates that a fully-lined channel with unreinforced vegetation has a maximum permissible velocity of 5 feet per second (fps). Due to the dense cover and mature vegetation, the permissible velocity when erosion can begin is likely greater than 5 fps in most of the natural stream areas. Table 5-13 indicates that 5 fps is equivalent to an unvegetated channel containing cobbles (grain

size from 64 to 256 mm) and shingles (rounded cobbles). In comparison, coarse gravel (19 to 75 mm) has a maximum permissible velocity of 4 fps. Based on this information, the uniformly vegetated natural streams within Buena Vista Creek and the West Tributary have an equivalent grain size of at least 64 mm.

In addition to the material size, there are several factors that establish the erodibility of a channel such as the flow rate (i.e., size of the tributary area), grade controls, channel slope, vegetative cover, channel planform, etc. The Introduction of the SCCWRP *Hydromodification Screening Tools: Field Manual* identifies several of these factors. When multiple factors influence erodibility, it is appropriate to perform the more detailed SCCWRP analysis, which is to analyze a channel according to SCCWRP's transitional/intermediate bed procedure. This requires the most rigorous steps and will generate the appropriate results given the range of factors that define erodibility. Dr. Eric Stein from SCCWRP, who co-authored the *Hydromodification Screening Tools: Field Manual* in the *Final Hydromodification Management Plan* (HMP), indicated that it would be appropriate to analyze channels with multiple factors that impact erodibility using the transitional/intermediate bed procedure. Consequently, this procedure was used to produce more accurate results.

Transitional/intermediate beds cover a wide susceptibility/potential response range and need to be assessed in greater detail to develop a weight of evidence for the appropriate screening rating. The three primary risk factors used to assess vertical susceptibility for channels with transitional/intermediate bed materials are:

1. Armoring potential – three states (Checklist 1)
2. Grade control – three states (Checklist 2)
3. Proximity to regionally-calibrated incision/braiding threshold (Mobility Index Threshold – Probability Diagram)

These three risk factors are assessed using checklists and a diagram (see Appendix B), and the results of each are combined to provide a final vertical susceptibility rating for the intermediate/transitional bed-material group. Each checklist and diagram contains a Category A, B, or C rating. Category A is the most resistant to vertical changes while Category C is the most susceptible.

Checklist 1 determines armoring potential of the channel bed. The channel bed along all of the reaches is within Category B, which represents intermediate bed material within unknown armoring potential due to a surface veneer (and/or vegetation). The soil was probed and penetration was relatively difficult through the underlying layer. As seen in the figures, all the channel bed areas either contain a gravel layer and/or dense vegetation.

Checklist 2 determines grade control characteristics of the channel bed. This is based on the spacing of the grade controls. Reach 6 below POC 1 and POC 2 encompasses the Hanson channel, which contains multiple grade controls (see Figures 1 through 4), so this area falls within Category A on Checklist 2. Portions of Reach 7 have eroded to bedrock (see Figures 15

and 16), so this area also falls within Category A on Checklist 2. In all of these reaches, the grade control spacing meets the threshold in Category A.

SCCWRP states that grade controls can be natural. Examples are vegetation or confluences with a larger waterbody. As verified during the site investigation, each of the remaining reaches (1 through 5, 8, and 9) contains dense, mature vegetation (see the figures). The plant roots and fallen tree trunks serve as a natural grade control. The spacing of these is much closer than the 50 meters identified in the checklist. Further evidence of the effectiveness of the natural grade controls is the absence of headcutting and mass wasting (large vertical erosion of a channel bank). Based on this information, each remaining reach is within Category A on Checklist 2.

The Mobility Index Threshold is a probability diagram that depicts the risk of incising or braiding based on the potential stream power of the valley relative to the median particle diameter. The threshold is based on regional data from Dr. Howard Chang of Chang Consultants and others. The probability diagram is based on  $d_{50}$  as well as the Screening Index determined in the initial desktop analysis (see Appendix A).  $d_{50}$  is derived from a pebble count in which a minimum of 100 particles are obtained along transects at the site. SCCWRP states that if fines less than ½-inch thick are at a sample point, it is appropriate to sample the coarser buried substrate. The  $d_{50}$  value is the particle size in which 50 percent of the particles are smaller and 50 percent are larger.

Pebble counts were performed within Buena Vista Creek, the Middle Tributary, and the West Tributary. The results are included in Appendix B. Pebble counts were combined for Reaches 1 to 5 and for Reach 8 and 9 because the bed material sizes within these reaches are relatively uniform. The results show a  $d_{50}$  of 16 millimeters for Reaches 1 to 5, 32 mm for Reach 6, 32 mm for Reach 7, and 8 mm for Reaches 8 and 9. The screening index for the associated reaches are tabulated in Appendix A. For Reaches 1 to 5 as well as 8 and 9, the greatest screening index value was used because this will generate the greatest erosion susceptibility. Plotting the  $d_{50}$  and screening index values on the Mobility Index Threshold diagram shows that all of the reaches have a less than 50 percent probability of incising or braiding, which falls within Category A.

The overall vertical rating is determined from the Checklist 1, Checklist 2, and Mobility Index Threshold results. The scoring is based on the following values:

Category A = 3, Category B = 6, Category C = 9

The vertical rating score is based on these values and the equation:

$$\begin{aligned}\text{Vertical Rating} &= [(\text{armoring} \times \text{grade control})^{1/2} \times \text{screening index score}]^{1/2} \\ &= [(6 \times 3)^{1/2} \times 3]^{1/2} \\ &= 3.6\end{aligned}$$

Since the vertical rating is less than 4.5, each reach has a low threshold for vertical susceptibility.

### Lateral Stability

The purpose of the lateral decision tree (Figure 6-5 from County of San Diego HMP included in Figure 29) is to assess the state of the channel banks with a focus on the risk of widening. Channels can widen from either bank failure or through fluvial processes such as chute cutoffs, avulsions, and braiding. Widening through fluvial avulsions/active braiding is a relatively straightforward observation. If braiding is not already occurring, the next logical step is to assess the condition of the banks. Banks fail through a variety of mechanisms; however, one of the most important distinctions is whether they fail in mass (as many particles) or by fluvial detachment of individual particles. Although much research is dedicated to the combined effects of weakening, fluvial erosion, and mass failure, SCCWRP found it valuable to segregate bank types based on the inference of the dominant failure mechanism (as the management approach may vary based on the dominant failure mechanism). A decision tree (Form 4 in Appendix B) is used in conducting the lateral susceptibility assessment. Definitions and photographic examples are also provided below for terms used in the lateral susceptibility assessment.

The first step in the decision tree is to determine if lateral adjustments are occurring. The adjustments can take the form of extensive mass wasting (greater than 50 percent of the banks are exhibiting planar, slab, or rotational failures and/or scalloping, undermining, and/or tension cracks). The adjustments can also involve extensive fluvial erosion (significant and frequent bank cuts on over 50 percent of the banks). The banks are intact in the photographs included in the figures. The relatively uniform, dense vegetative cover on many of the banks is evidence of the absence of large lateral adjustments. Neither lateral mass wasting nor extensive lateral fluvial erosion was evident within any of the reaches during a field investigation. Reach 7 was the only portion of the entire study area that exhibited bank erosion. However, the erosion is not associated with lateral changes, but with historic vertical changes. The bottom of Reach 7 has reached bedrock, so future vertical changes will be limited.

The next step in the Form 4 decision tree is to assess the consolidation of the bank material. The banks were moderate to well-consolidated. This determination was made because the banks were difficult to penetrate with a probe. In addition, the banks showed limited evidence of crumbling and were composed of well-packed particles (see figures).

Form 6 (see Appendix B) is used to assess the probability of mass wasting. Form 6 identifies a 10, 50, and 90 percent probability based on the bank angle and bank height. From the 2-foot contour topographic mapping and site investigation, the bank angle in Reaches 1 through 6, 8 and 9 are at a 2 to 1 (horizontal to vertical) slope (26.6 degrees) or less. Form 6 shows that the probability of mass wasting and bank failure has less than 10 percent risk for a 26.6 degree bank angle or less regardless of the bank height.

The bank slope on Reach 7 is approximately 1:1 or 45 degrees. The 10-year flow in Reach 7 from Form 1 in Appendix A is 28 cubic feet per second. A normal depth analysis was performed (see Appendix B), which shows that the 10-year flow depth in Reach 7 will be approximately 0.5 feet. This represents the bank height subject to erosion by flows. Plotting this flow depth versus the 45 degree bank angle on Form 6, shows that the probability of mass wasting in Reach 7 is less than 10 percent.

The final two steps in the Form 4 decision tree are based on the braiding risk determined from the vertical rating as well as the Valley Width Index (VWI) calculated in Appendix A. If the vertical rating is high, the braiding risk is considered to be greater than 50 percent. Excessive braiding can lead to lateral bank failure. For all of the reaches the vertical rating is low, so the braiding risk is less than 50 percent. There was no evidence of braiding in the field. Furthermore, a VWI greater than 2 represents channels unconfined by bedrock or hillslope and, hence, subject to lateral migration. The VWI calculations in the spreadsheet in Appendix A show that the VWI for each reach is less than 2.

From the above steps, the lateral susceptibility rating is low (red circles are included on the Form 4: Lateral Susceptibility Field Sheet decision tree in Appendix B showing the decision path).

## **CONCLUSION**

The SCCWRP channel screening tools were used to assess the downstream channel susceptibility for McMillin Land Development's Quarry Creek project. The project runoff will be collected by Buena Vista Creek, a Middle Tributary to Buena Vista Creek, and a West Tributary to Buena Vista Creek. Each of these watercourses is natural, so has a susceptibility to erosion. The project runoff will discharge into the watercourses at various storm drain outfalls, which are the points of compliance. A downstream channel assessment was performed for each point of compliance. The results indicate a low threshold for vertical and lateral susceptibilities for all of the study reaches. This is consistent with the field conditions because the majority of the downstream watercourses are either engineered channels or densely vegetated channels exhibiting limited evidence of erosion.

The HMP requires that these results be compared with the critical stress calculator results incorporated in the County of San Diego's BMP Sizing Calculator. The BMP Sizing Calculator critical stress results are included in Appendix B for the reaches immediately below each point of compliance (Reach 5, 6, 7, and 8). The critical stress results returned a low threshold. Therefore, the SCCWRP analyses and critical stress calculator demonstrate that the entire project can be designed assuming a low susceptibility to erosion, i.e.,  $0.5Q_2$ .



**Figure 1. Upper End of Buena Vista Creek Study Area near POC 1 and 2**



**Figure 2. Looking Downstream at Hanson Channel from Upper End of Buena Vista Creek**



**Figure 3. Looking Downstream Within Hanson Channel**



**Figure 4. Looking Upstream at Hanson Channel**



**Figure 5. Looking Downstream of the Hanson Channel at Buena Vista Creek**



**Figure 6. Rocks and Gravel in Buena Vista Creek Channel Bed Downstream of Hanson Channel**



**Figure 7. Dense Vegetation at Edge of Buena Vista Creek Adjacent to Access Road**



**Figure 8. Dense Vegetation in Buena Vista Creek Looking Upstream from East End of Westerly Segment of Haymar Drive**



**Figure 9. Looking Upstream at Buena Vista Creek within Driving Range**



**Figure 10. Looking Downstream at Buena Vista Creek from Haymar Drive Bridge**



**Figure 11. Gravel Bed under Haymar Drive Bridge over Buena Vista Creek**



**Figure 12. Looking Downstream along Buena Vista Creek towards El Camino Real**



**Figure 13. Concrete-Lined Trapezoidal Channel near El Camino Real (vegetation growth on concrete)**



**Figure 14. Gravel on Buena Vista Creek Channel Bed near El Camino Real**



**Figure 15. Bedrock at Upper End of Middle Tributary**



**Figure 16. Looking North along Middle Tributary towards Buena Vista Creek**



**Figure 17. Looking East towards Confluence of Buena Vista Creek and West Tributary**



**Figure 18. Looking Upstream along Densely Vegetated West Tributary**



**Figure 19. Looking Downstream along Densely Vegetated West Tributary**



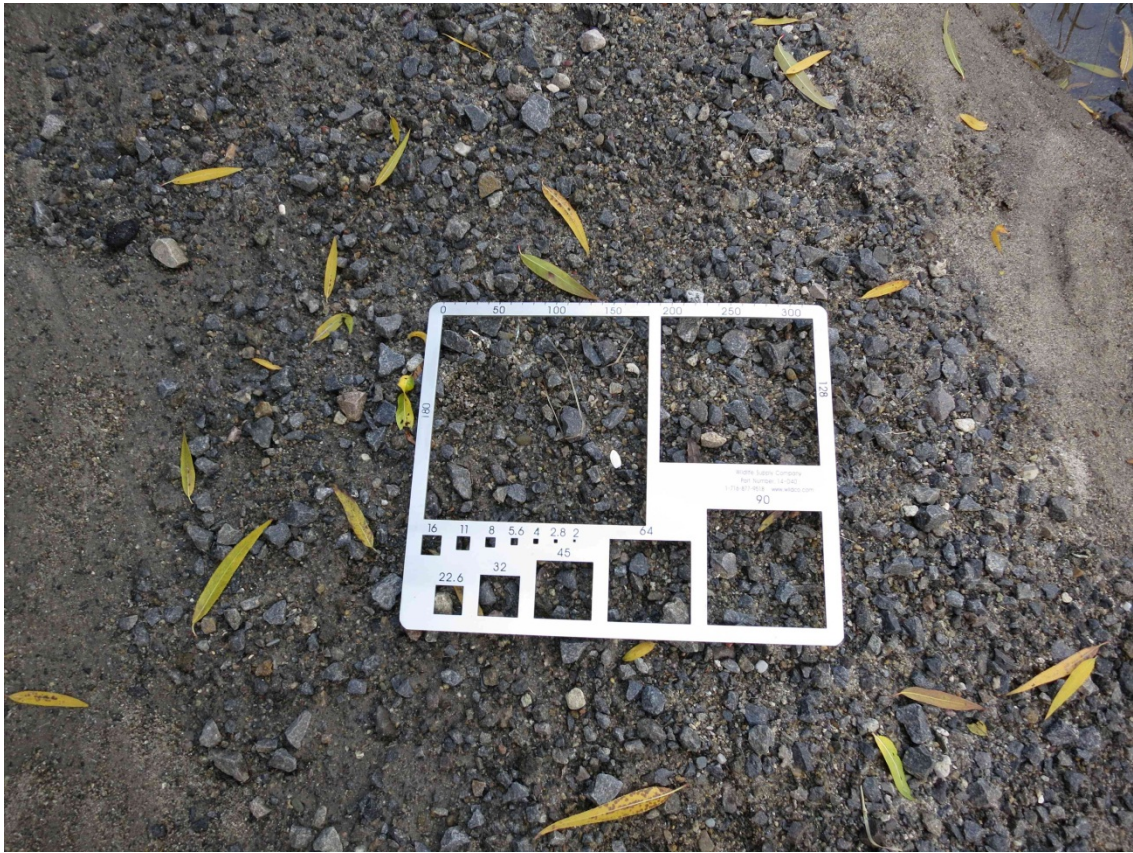
**Figure 20. Vegetation within West Tributary Floodplain**



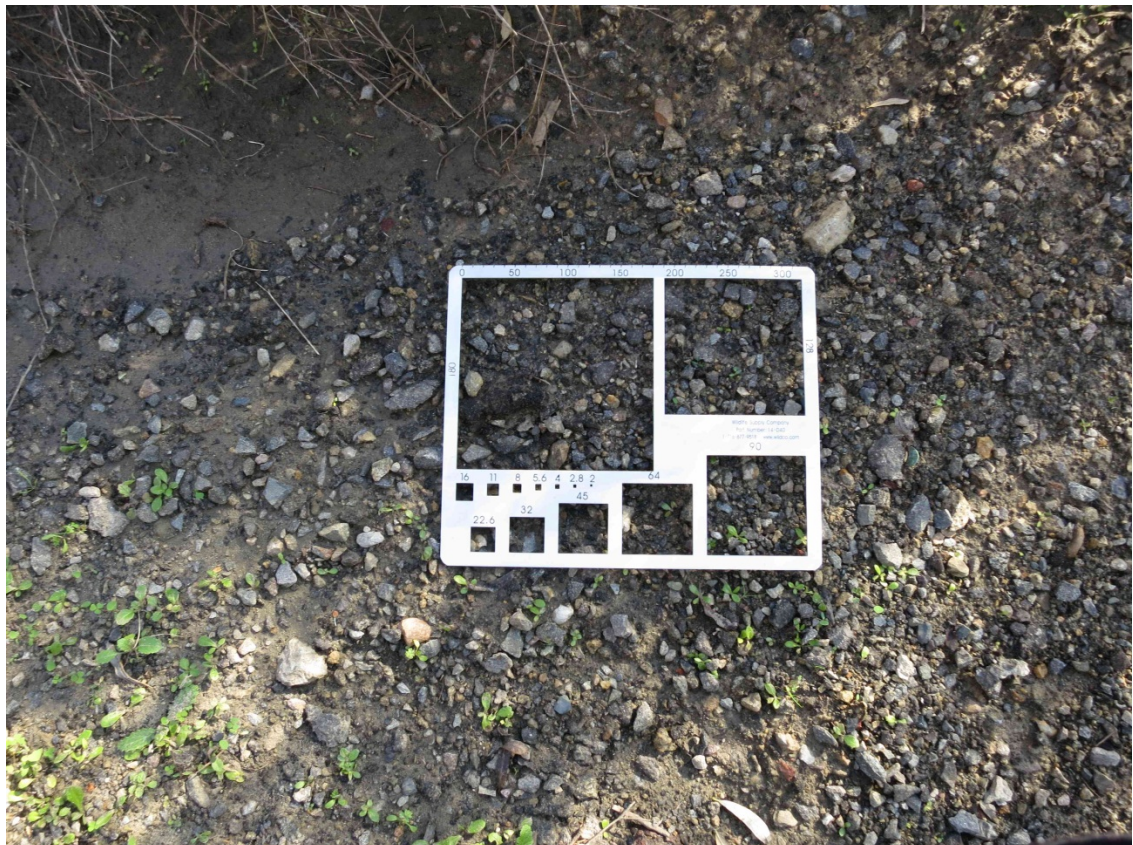
**Figure 21. Channel Bed Material within Hanson Channel of Buena Vista Creek**



**Figure 22. Channel Bed Material near East End of Westerly Segment of Haymar Drive**



**Figure 23. Channel Bed Material near Haymar Drive Bridge over Buena Vista Creek**



**Figure 24. Channel Bed Material at Upstream End of Buena Vista Creek Concrete Trapezoidal Channel**



**Figure 25. Channel Bed Material at Downstream End of Concrete Trapezoidal Channel**



**Figure 26. Channel Bed Material at Middle Tributary**



**Figure 27. Channel Bed Material at East Tributary**

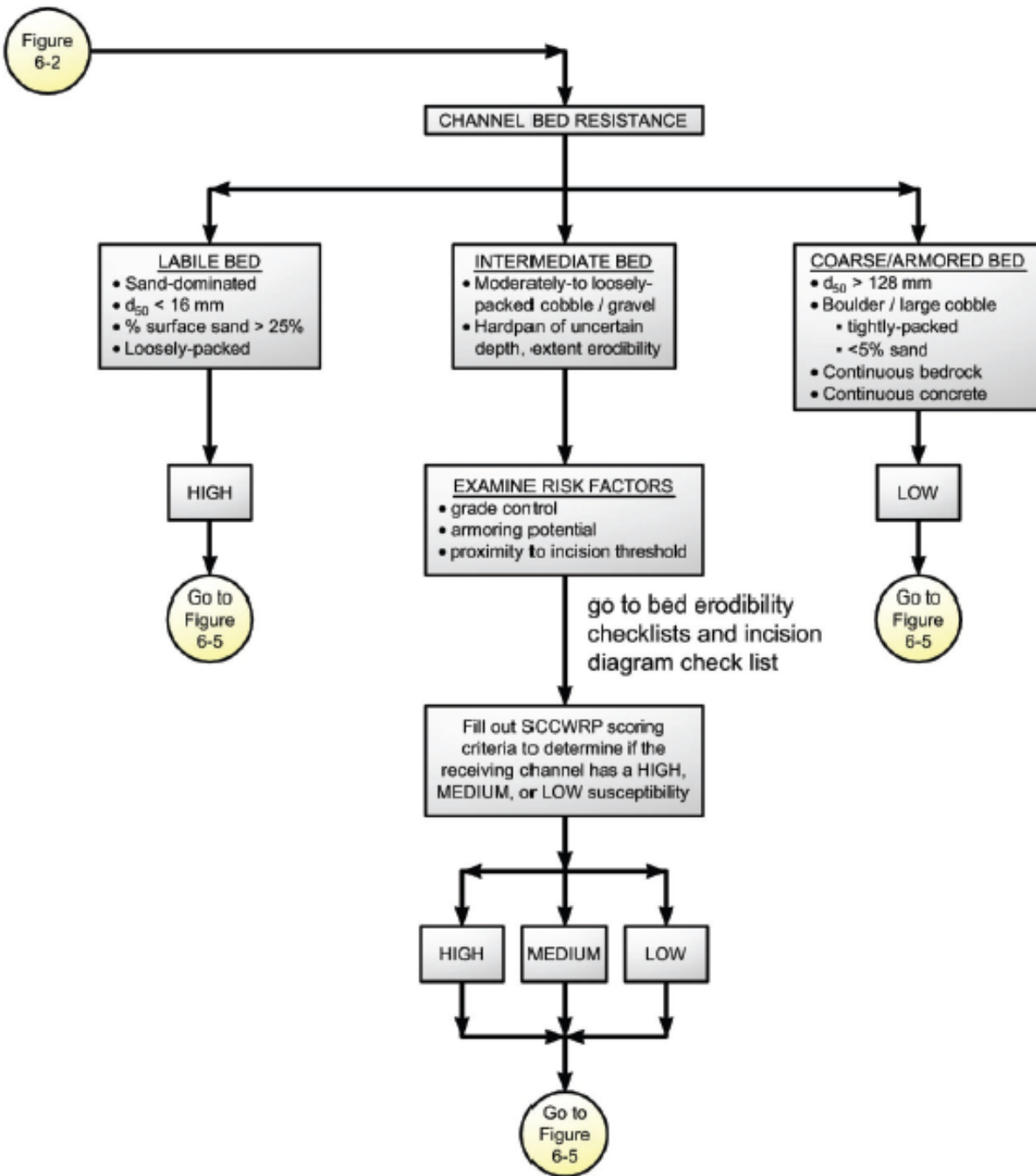


Figure 6-4. SCCWRP Vertical Susceptibility

Figure 28. SCCWRP Vertical Channel Susceptibility Matrix

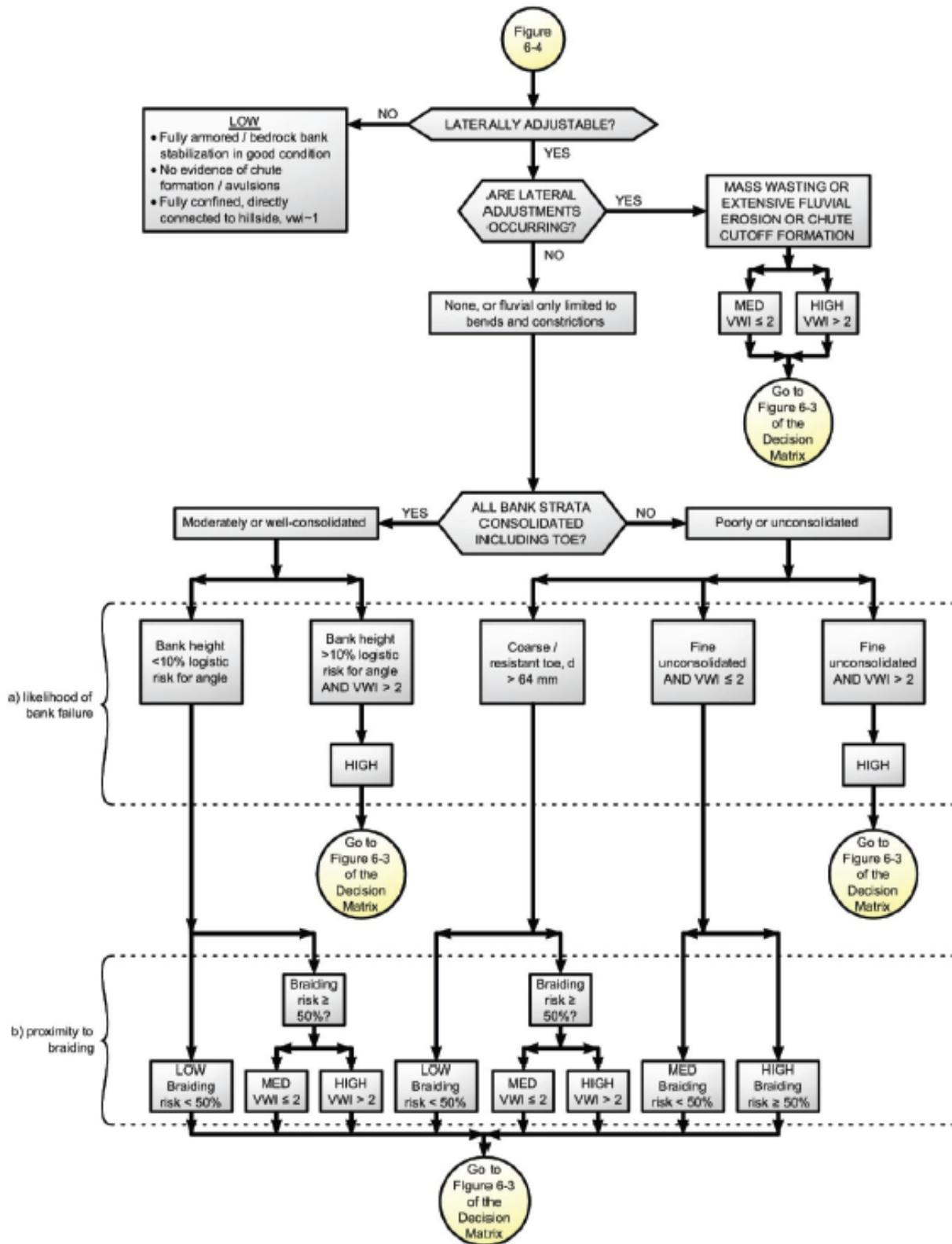


Figure 6-5. Lateral Channel Susceptibility

Figure 29. SCCWRP Lateral Channel Susceptibility Matrix

# **APPENDIX A**

## **SCCWRP INITIAL DESKTOP ANALYSIS**

## FORM 1: INITIAL DESKTOP ANALYSIS

### Complete all shaded sections.

IF required at multiple locations, circle one of the following site types:

**Applicant Site / Upstream Extent / Downstream Extent**

**Location:** Latitude: 33.1784 Longitude: -117.3036

Description (river name, crossing streets, etc.): Buena Vista Creek, Middle Tributary to Buena Vista Creek, West Tributary to Buena Vista Creek

**GIS Parameters:** The International System of Units (SI) is used throughout the assessment as the field standard and for consistency with the broader scientific community. However, as the singular exception, US Customary units are used for contributing drainage area (A) and mean annual precipitation (P) to apply regional flow equations after the USGS. See SCCWRP Technical Report 607 for example measurements and "[Screening Tool Data Entry.xls](#)" for automated calculations.

**Form 1 Table 1. Initial desktop analysis in GIS.**

Symbol	Variable	Description and Source	Value
Watershed properties (English units)	<b>A</b> Area (mi <sup>2</sup> )	Contributing drainage area to screening location via published Hydrologic Unit Codes (HUCs) and/or ≤ 30 m National Elevation Data (NED), USGS seamless server	See attached Form 1 table on next page for calculated values for each reach.
	<b>P</b> Mean annual precipitation (in)	Area-weighted annual precipitation via USGS delineated polygons using records from 1900 to 1960 (which was more significant in hydrologic models than polygons delineated from shorter record lengths)	
Site properties (SI units)	<b>S<sub>v</sub></b> Valley slope (m/m)	Valley slope at site via NED, measured over a relatively homogenous valley segment as dictated by hillslope configuration, tributary confluences, etc., over a distance of up to ~500 m or 10% of the main-channel length from site to drainage divide	
	<b>W<sub>v</sub></b> Valley width (m)	Valley bottom width at site between natural valley walls as dictated by clear breaks in hillslope on NED raster, irrespective of potential armoring from floodplain encroachment, levees, etc. (imprecise measurements have negligible effect on rating in wide valleys where VWI is >> 2, as defined in lateral decision tree)	

**Form 1 Table 2. Simplified peak flow, screening index, and valley width index. Values for this table should be calculated in the sequence shown in this table, using values from Form 1 Table 1.**

Symbol	Dependent Variable	Equation	Required Units	Value
<b>Q<sub>10cfs</sub></b>	10-yr peak flow (ft <sup>3</sup> /s)	$Q_{10cfs} = 18.2 * A^{0.87} * P^{0.77}$	A (mi <sup>2</sup> ) P (in)	See attached Form 1 table on next page for calculated values for each reach.
<b>Q<sub>10</sub></b>	10-yr peak flow (m <sup>3</sup> /s)	$Q_{10} = 0.0283 * Q_{10cfs}$	Q <sub>10cfs</sub> (ft <sup>3</sup> /s)	
<b>INDEX</b>	10-yr screening index (m <sup>1.5</sup> /s <sup>0.5</sup> )	$INDEX = S_v * Q_{10}^{0.5}$	S <sub>v</sub> (m/m) Q <sub>10</sub> (m <sup>3</sup> /s)	
<b>W<sub>ref</sub></b>	Reference width (m)	$W_{ref} = 6.99 * Q_{10}^{0.438}$	Q <sub>10</sub> (m <sup>3</sup> /s)	
<b>VWI</b>	Valley width index (m/m)	$VWI = W_v / W_{ref}$	W <sub>v</sub> (m) W <sub>ref</sub> (m)	

(Sheet 1 of 1)

## SCCWRP FORM 1 ANALYSES

Reach	Area A, sq. mi.	Mean Annual Precip. P, inches	Valley Slope Sv, m/m	Valley Width Wv, m	10-Year Flow Q10cfs, cfs	10-Year Flow Q10, cms
1	17.33	13.3	0.0067	30.5	1597	45.2
2	16.75	13.3	0.0022	7.0	1550	43.9
3	16.43	13.3	0.0074	15.0	1524	43.1
4	14.91	13.3	0.0071	10.0	1400	39.6
5	14.50	13.3	0.0076	5.0	1367	38.7
6	14.28	13.3	0.0014	45.0	1349	38.2
7	0.17	13.3	0.0659	2.5	28	0.8
8	0.48	13.3	0.0156	18.0	70	2.0
9	0.32	13.3	0.0138	3.0	50	1.4

Reach	10-Year Screening Index INDEX	Reference Width Wref, m	Valley Width Index VWI, m/m
1	0.045	37.1	0.82
2	0.015	36.6	0.19
3	0.049	36.4	0.41
4	0.045	35.0	0.29
5	0.047	34.7	0.14
6	0.009	34.5	1.31
7	0.059	6.3	0.39
8	0.022	9.5	1.90
9	0.016	8.1	0.37

### Notes:

The areas for Reach 1 through 6 were determined from a Hunsaker study.

The area for Reach 7 was determined from PDC's Quarry Creek hydrology study.

The area for Reach 8 and 9 was determined from the Watershed Delineation exhibit in this appendix.

The mean annual precipitation was obtained from the County of San Diego's BMP Calculator in this appendix.

The valley slope was determined from the elevations and flow lengths from the Study Area Exhibit.

The valley width was estimated from the topographic mapping on the Study Area Exhibit and a site investigation.

The 10-year flow, screening index, reference width, and valley width index are calculated from the equations on Form 1 (see Appendix A).



# Hunsaker & Associates San Diego, Inc.

Planning • Engineering • Surveying • GPS

**THE FOLLOWING THREE SHEETS  
PROVIDE THE BUENA VISTA CREEK  
WATERSHED AREAS AT COLLEGE BLVD.  
AND EL CAMINO REAL**

HYDROLOGIC STUDY

FOR

BUENA VISTA CREEK BASIN

Prepared for:

The City of  
Oceanside, California

Prepared by:

HUNSAKER & ASSOCIATES SAN DIEGO, INC.

10179 Huennekens Street

San Diego, CA 92121

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Mark A. Brencick

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W.O. No. 1509-1

Date: June 23, 1994



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wo 1509-1

10179 Huennekens Street • San Diego, CA 92121 • (619) 558-4500 • FAX: (619) 558-1414

Offices: San Diego • Irvine • Riverside/San Bernardino

David Hammar • Jack Hill

Dave  
Hammar  
Eric  
Mesa/90

### III Summary Of Results

The results from the HEC-1 run were as follows:

Subbasin	Location	100 Year Runoff from H&A Report (CFS)	100 Year Runoff from Willdan Report (CFS)
1A	Brengle Terrace Park Detention Basin	1028	*
1B	West of Vista City Hall in Buena Vista Creek	1932	3960
2A	South Santa Fe Road	3025	*
2B	Monte Vista Detention Basin	181	*
2C	Conflued with Subbasin 2A	4703	*
2D	Melrose Avenue	6906	8570
3	College Avenue	10306	*
4	El Camino Real	12802	12790
5	Buena Vista Lagoon	13027	13030
6	Pacific Ocean	14167	*

\* Indicates there was not a corresponding analysis point in the Willdan Report.

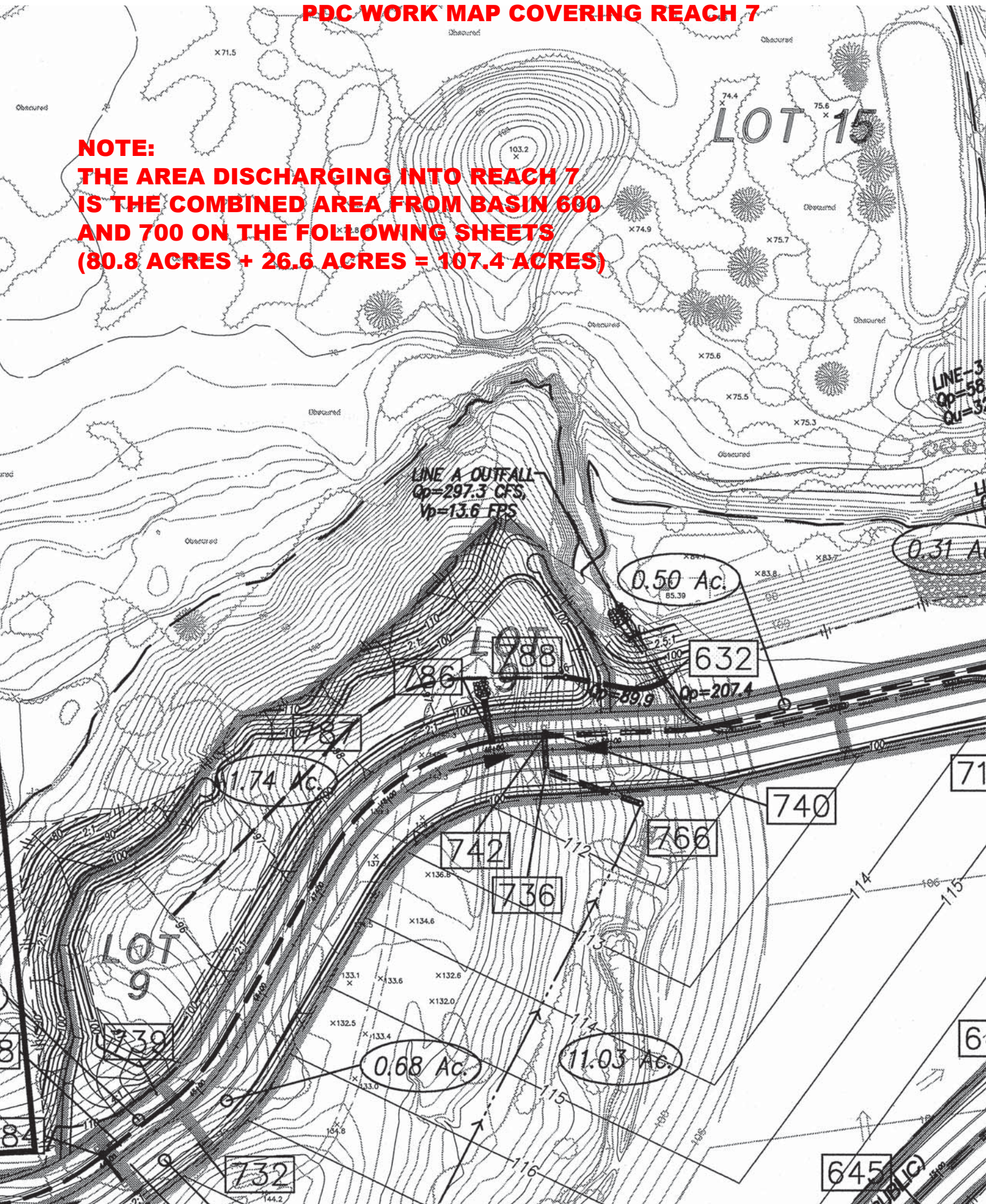
In the higher reaches of the Buena Vista Creek Basin, the H&A results were considerably lower than the Willdan results. This may be due to the fact that the H&A report considered the two detention basins to be operational and functioning. However, as the runoff travels down the Basin, the Willdan results and the H&A results become increasingly closer - the flow entering the Buena Vista Lagoon at the bottom of the Basin is essentially the same.

RUNOFF SUMMARY  
FLOW IN CUBIC FEET PER SECOND  
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD			BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
				6-HOUR	24-HOUR	72-HOUR			
HYDROGRAPH AT	SUB1A	2572.	1.33	465.	339.	339.	2.64		
ROUTED TO	ROUTE	1028.	2.25	464.	339.	339.	2.64	437.54	2.25
HYDROGRAPH AT	SUB1B	1932.	1.17	697.	508.	508.	3.98		
HYDROGRAPH AT	SUB2A	3025.	1.17	869.	633.	633.	4.97		
HYDROGRAPH AT	SUB2B	1264.	1.08	168.	123.	123.	.95		
ROUTED TO	ROUTE	181.	2.50	152.	122.	122.	.95	493.54	2.50
HYDROGRAPH AT	SUB2C	1678.	1.17	377.	289.	289.	2.32		
2 COMBINED AT	COMB	4703.	1.17	1246.	923.	923.	7.29		
HYDROGRAPH AT	SUB2D	6906.	1.17	1590.	1174.	1174.	9.35		
HYDROGRAPH AT	SUB 3	10306.	1.33	2181.	1609.	1609.	13.35		
HYDROGRAPH AT	SUB 4	12802.	1.42	2698.	1988.	1988.	17.33		
HYDROGRAPH AT	SUB 5	13027.	1.50	2894.	2133.	2133.	18.94		
HYDROGRAPH AT	SUB 6	14167.	1.50	3217.	2372.	2372.	21.55		

# PDC WORK MAP COVERING REACH 7

**NOTE:**  
**THE AREA DISCHARGING INTO REACH 7**  
**IS THE COMBINED AREA FROM BASIN 600**  
**AND 700 ON THE FOLLOWING SHEETS**  
**(80.8 ACRES + 26.6 ACRES = 107.4 ACRES)**



Process from Point/Station 646.000 to Point/Station 632.000  
\*\*\*\* PIPEFLOW TRAVEL TIME (Program estimated size) \*\*\*\*

---

Upstream point/station elevation = 102.500(Ft.)  
Downstream point/station elevation = 93.000(Ft.)  
Pipe length = 851.00(Ft.) Manning's N = 0.013  
No. of pipes = 1 Required pipe flow = 207.422(CFS)  
Nearest computed pipe diameter = 54.00(In.)  
Calculated individual pipe flow = 207.422(CFS)  
Normal flow depth in pipe = 44.16(In.)  
Flow top width inside pipe = 41.70(In.)  
Critical Depth = 48.98(In.)  
Pipe flow velocity = 14.89(Ft/s)  
Travel time through pipe = 0.95 min.  
Time of concentration (TC) = 9.87 min.  
End of computations, total study area = 80.780 (Ac.)

**PDC RATIONAL METHOD RESULTS FOR  
BASIN 600 WHICH OUTLETS INTO REACH 7**

Subarea runoff = 3.153(CFS)  
Total initial stream area = 1.740(Ac.)

++++  
Process from Point/Station 787.000 to Point/Station 788.000  
\*\*\*\* CONFLUENCE OF MINOR STREAMS \*\*\*\*

---

Along Main Stream number: 1 in normal stream number 2  
Stream flow area = 1.740(Ac.)  
Runoff from this stream = 3.153(CFS)  
Time of concentration = 11.68 min.  
Rainfall intensity = 4.419(In/Hr)  
Summary of stream data:

Stream No.	Flow rate (CFS)	TC (min)	Rainfall Intensity (In/Hr)
------------	-----------------	----------	----------------------------

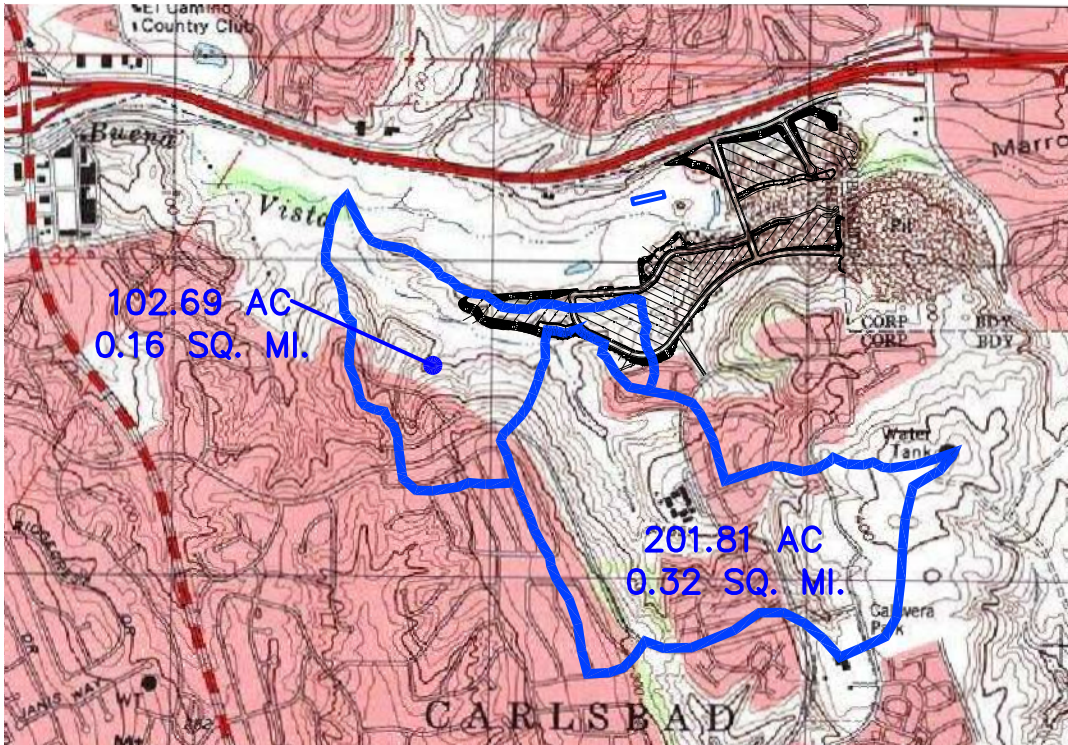
1	87.775	7.82	5.728
2	3.153	11.68	4.419
Qmax(1) =			
	1.000 *	1.000 *	87.775) +
	1.000 *	0.669 *	3.153) + = 89.884
Qmax(2) =			
	0.772 *	1.000 *	87.775) +
	1.000 *	1.000 *	3.153) + = 70.872

Total of 2 streams to confluence:  
Flow rates before confluence point:  
87.775 3.153  
Maximum flow rates at confluence using above data:  
89.884 70.872

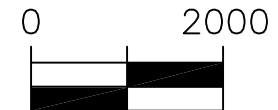
Area of streams before confluence:  
24.900 1.740

Results of confluence:  
Total flow rate = 89.884(CFS)  
Time of concentration = 7.815 min.  
Effective stream area after confluence = 26.640(Ac.)  
End of computations, total study area = 26.640 (Ac.)

**PDC RATIONAL METHOD RESULTS FOR  
BASIN 700 WHICH OUTLETS INTO REACH 7**



GRAPHIC SCALE



1 INCH = 2,000 FEET

NOTE:

THIS EXHIBIT SHOWS THE DRAINAGE  
AREAS TRIBUTARY TO REACHES 8  
AND 9 ASSOCIATED WITH POINT OF  
COMPLIANCE 5.

## WATERSHED DELINEATION BUENA VISTA CREEK WEST TRIBUTARY



# Define Drainage Basins

Basin: Quarry Creek at Buena Vista Creek

Project: QUARRY CREEK

Start

Project

Basin

POC

Export

## Manage Your Basins

Create a new Basin by clicking the New button and scroll down to view entry. Alternatively, select an existing Basin from table and view properties below. Click Edit button to change Basin properties then press Save to commit changes.

New

Edit

Save

Delete

Name

Quarry Creek at Buena Vista Creek

Description: Quarry Creek

Design Goal: Treatment + Flow Control

Rainfall Basin: Oceanside

Point of Compliance: Buena Vista Creek + Tributaries

Project Basin Area (ac): 8500.00

Mean Annual Precipitation (in): 13.3

# **APPENDIX B**

## **SCCWRP FIELD SCREENING DATA**

**Table 5-13** Maximum Permissible Velocities for Lined and Unlined Channels

Material or Lining	Maximum Permissible Average Velocity* (ft/sec)
<b>Natural and Improved Unlined Channels</b>	
Fine Sand, Colloidal .....	1.50
Sandy Loam, Noncolloidal .....	1.75
Silt Loam, Noncolloidal .....	2.00
Alluvial Silts, Noncolloidal .....	2.00
Ordinary Firm Loam .....	2.50
Volcanic Ash .....	2.50
Stiff Clay, Very Colloidal .....	3.75
Alluvial Silts, Colloidal .....	3.75
Shales And Hardpans .....	6.00
Fine Gravel .....	2.50
Graded Loam To Cobbles When Noncolloidal .....	3.75
Graded Silts To Cobbles When Colloidal .....	4.00
Coarse Gravel, Noncolloidal .....	4.00
<b>Cobbles And Shingles .....</b>	<b>5.00</b>
Sandy Silt .....	2.00
Silty Clay .....	2.50
Clay .....	6.00
Poor Sedimentary Rock .....	10.0
<b>Fully-Lined Channels</b>	
<b>Unreinforced Vegetation .....</b>	<b>5.0</b>
Reinforced Turf .....	10.0
Loose Riprap .....	per Table 5-2
Grouted Riprap .....	25.0
Gabions .....	15.0
Soil Cement .....	15.0
Concrete .....	35.0

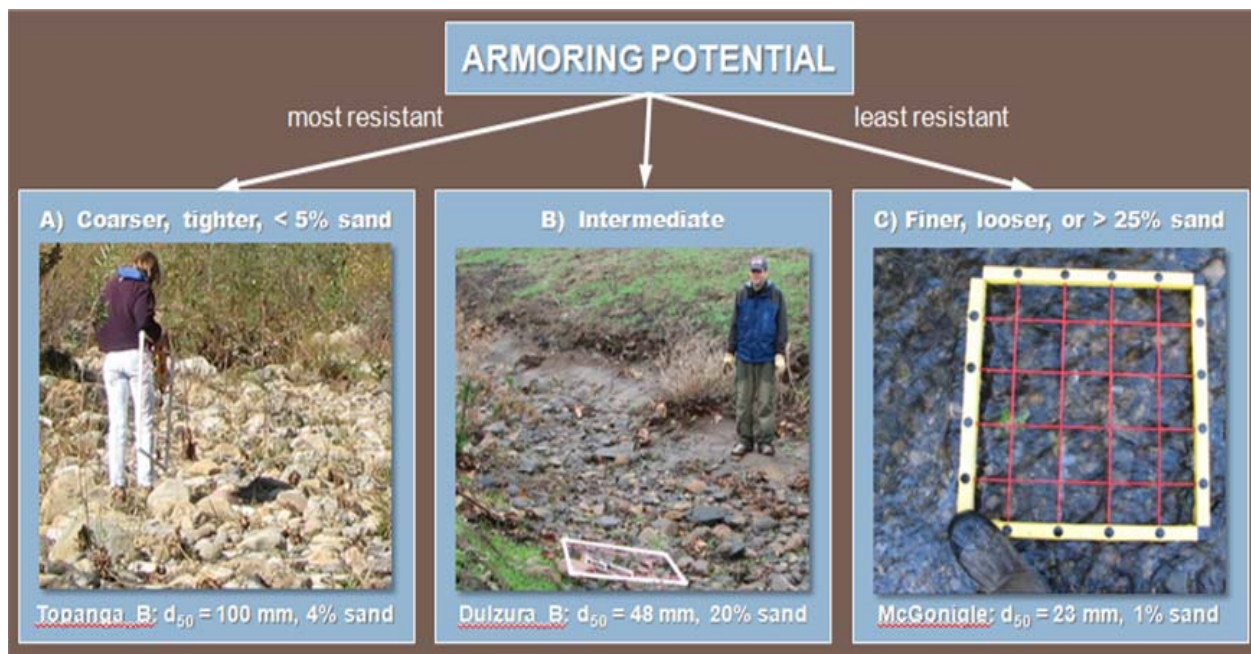
\* Maximum permissible velocity listed here is basic guideline; higher design velocities may be used, provided appropriate technical documentation from manufacturer.

## Form 3 Support Materials

**Form 3 Checklists 1 and 2, along with information recording in Form 3 Table 1, are intended to support the decisions pathways illustrated in Form 3 Overall Vertical Rating for Intermediate/Transitional Bed.**

## Form 3 Checklist 1: Armoring Potential

- |                                     |   |  |
|-------------------------------------|---|--|
| <input type="checkbox"/>            | A | A mix of coarse gravels and cobbles that are tightly packed with <5% surface material of diameter <2 mm  |
| <input checked="" type="checkbox"/> | B | Intermediate to A and C or hardpan of unknown resistance, spatial extent (longitudinal and depth), or unknown armoring potential due to surface veneer covering gravel or coarser layer encountered with probe |
| <input type="checkbox"/>            | C | Gravels/cobbles that are loosely packed or >25% surface material of diameter <2 mm   |



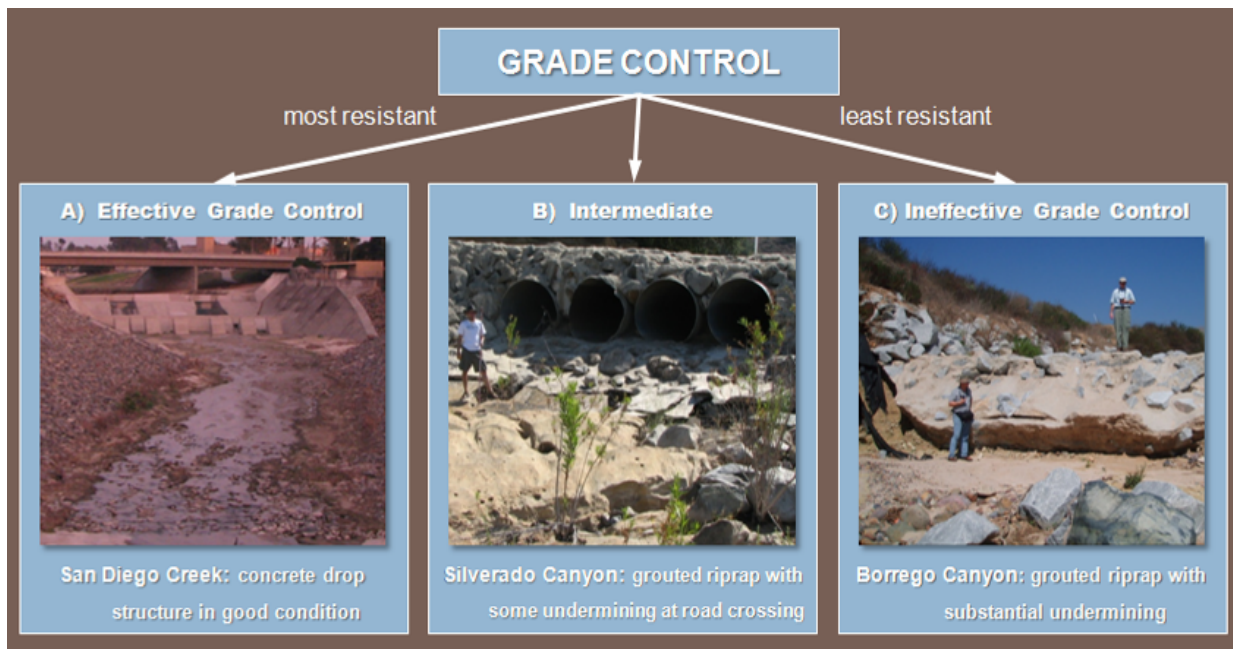
**Form 3 Figure 2. Armoring potential photographic supplement for assessing intermediate beds ( $16 < d_{50} < 128$  mm) to be used in conjunction with Form 3 Checklist 1.**

(Sheet 2 of 4)

**This sheet applies to Reaches 1 through 9**

### Form 3 Checklist 2: Grade Control

- X**      A      Grade control is present with spacing  $<50$  m or  $2/S_v$  m
- No evidence of failure/ineffectiveness, e.g., no headcutting ( $>30$  cm), no active mass wasting (analyst cannot say grade control sufficient if mass-wasting checklist indicates presence of bank failure), no exposed bridge pilings, no culverts/structures undermined
  - Hard points in serviceable condition at decadal time scale, e.g., no apparent undermining, flanking, failing grout
  - If geologic grade control, rock should be resistant igneous and/or metamorphic; For sedimentary/hardpan to be classified as 'grade control', it should be of demonstrable strength as indicated by field testing such as hammer test/borings and/or inspected by appropriate stakeholder
- B      Intermediate to A and C – artificial or geologic grade control present but spaced  $2/S_v$  m to  $4/S_v$  m or potential evidence of failure or hardpan of uncertain resistance
- C      Grade control absent, spaced  $>100$  m or  $>4/S_v$  m, or clear evidence of ineffectiveness



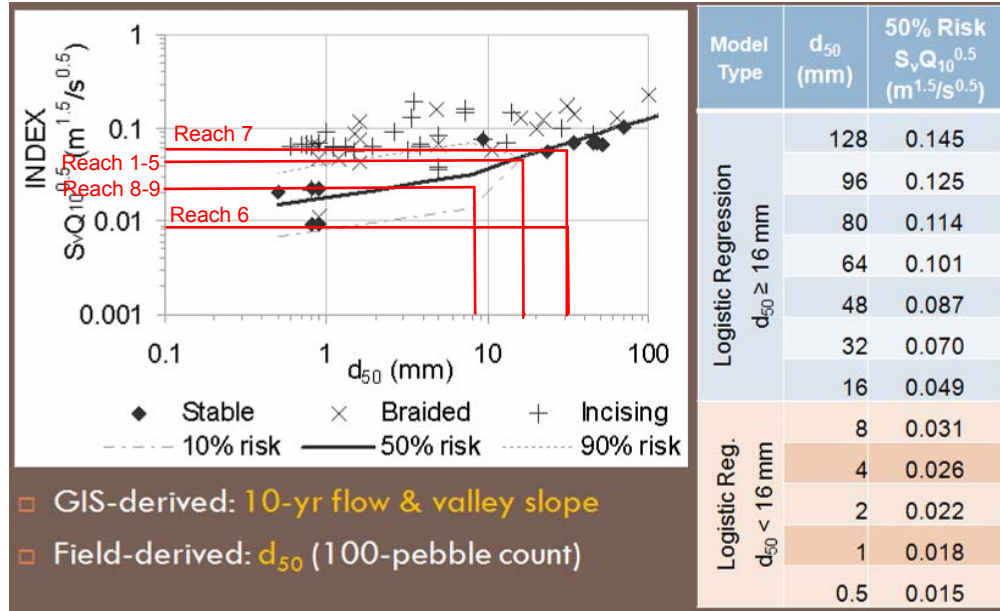
**Form 3 Figure 3. Grade-control (condition) photographic supplement for assessing intermediate beds ( $16 < d_{50} < 128$  mm) to be used in conjunction with Form 3 Checklist 2.**

(Sheet 3 of 4)

**This sheet applies to Reaches 1 through 9**

## Regionally-Calibrated Screening Index Threshold for Incising/Braiding

For transitional bed channels ( $d_{50}$  between 16 and 128 mm) or labile beds (channel not incised past critical bank height), use Form 3 Figure 3 to determine Screening Index Score and complete Form 3 Table 1.



Form 3 Figure 4. Probability of incising/braiding based on logistic regression of Screening Index and  $d_{50}$  to be used in conjunction with Form 3 Table 1.

Form 3 Table 1. Values for Screening Index Threshold (probability of incising/braiding) to be used in conjunction with Form 3 Figure 4 (above) to complete Form 3 Overall Vertical Rating for Intermediate/Transitional Bed (below).. Screening Index Score: A = <50% probability of incision for current  $Q_{10}$ , valley slope, and  $d_{50}$ ; B = Hardpan/ $d_{50}$  indeterminate; and C =  $\geq 50\%$  probability of incising/braiding for current  $Q_{10}$ , valley slope, and  $d_{50}$ .

$d_{50}$ (mm) From Form 2	$S_v Q_{10}^{0.5}$ ( $m^{1.5}/s^{0.5}$ ) From Form 1	$S_v Q_{10}^{0.5}$ ( $m^{1.5}/s^{0.5}$ ) 50% risk of incising/braiding from table in Form 3 Figure 3 above	Screening Index Score (A, B, C)

## Overall Vertical Rating for Intermediate/Transitional Bed

Calculate the overall Vertical Rating for Transitional Bed channels using the formula below. Numeric values for responses to Form 3 Checklists and Table 1 as follows: A = 3, B = 6, C = 9.

$$Vertical\ Rating = \sqrt{\{(\sqrt{\text{armoring} * \text{grade control}}) * \text{screening index score}\}}$$

Vertical Susceptibility based on Vertical Rating: <4.5 = LOW; 4.5 to 7 = MEDIUM; and >7 = HIGH.

(Sheet 4 of 4)

PEBBLE COUNT

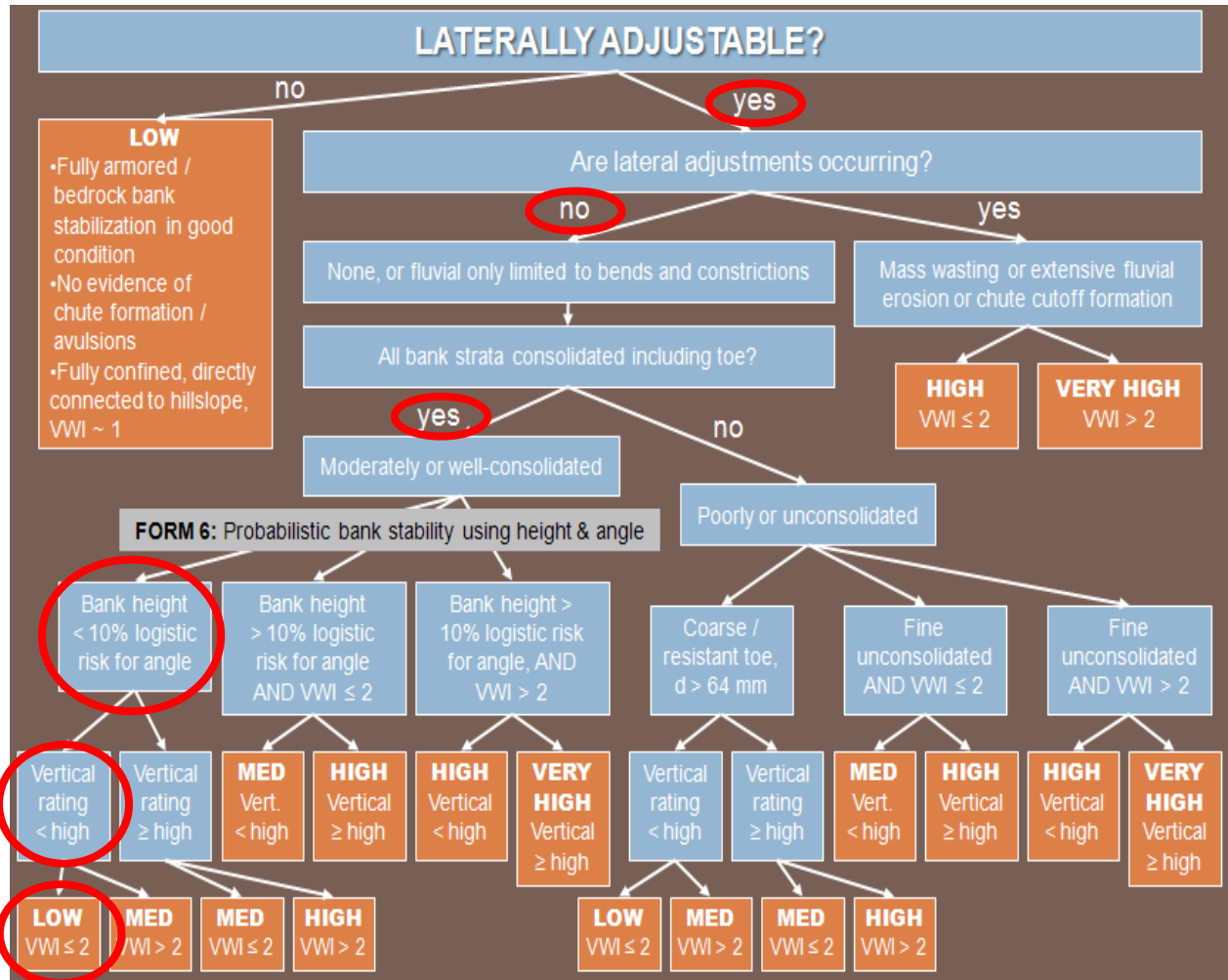
#	Reach 1 to 5 diameter, mm	Reach 6 diameter, mm	Reach 7 diameter, mm	Reach 8 and 9 diameter, mm	
1	2	5.5	2	2	
2	2	5.5	2	2	
3	2	5.5	2.8	2	
4	2	8	2.8	2	
5	2.8	8	2.8	2	
6	2.8	8	2.8	2	
7	2.8	8	4	2	
8	2.8	8	4	2	
9	2.8	8	4	2.8	
10	2.8	8	5.6	2.8	
11	4	8	5.6	2.8	
12	4	8	5.6	2.8	
13	4	11	5.6	2.8	
14	4	11	5.6	2.8	
15	4	11	5.6	2.8	
16	4	11	5.6	2.8	
17	4	11	8	4	
18	4	11	8	4	
19	5.6	11	8	4	
20	5.6	16	8	4	
21	5.6	16	8	4	
22	5.6	16	11	4	
23	5.6	16	11	4	
24	5.6	16	11	4	
25	5.6	16	11	4	
26	5.6	16	11	4	
27	5.6	22.6	11	4	
28	5.6	22.6	11	5.6	
29	5.6	22.6	11	5.6	
30	8	22.6	11	5.6	
31	8	22.6	11	5.6	
32	8	22.6	16	5.6	
33	8	22.6	16	5.6	
34	8	22.6	16	5.6	
35	8	22.6	16	5.6	
36	8	22.6	16	5.6	
37	8	22.6	16	5.6	
38	8	22.6	16	5.6	
39	11	22.6	22.6	5.6	
40	11	22.6	22.6	5.6	
41	11	22.6	22.6	5.6	
42	11	22.6	22.6	5.6	
43	11	22.6	22.6	5.6	
44	11	22.6	22.6	8	
45	11	32	22.6	8	
46	11	32	22.6	8	
47	11	32	22.6	8	
48	16	32	22.6	8	
49	16	32	22.6	8	
50	16	32	32	8	D50
51	16	32	32	8	
52	16	32	32	8	
53	16	32	32	8	
54	16	32	32	8	
55	16	32	32	8	
56	16	32	32	8	
57	16	32	32	8	
58	16	32	32	8	
59	16	45	32	8	

**PEBBLE COUNT**

#	Reach 1 to 5 diameter, mm	Reach 6 diameter, mm	Reach 7 diameter, mm	Reach 8 and 9 diameter, mm
60	16	45	32	8
61	16	45	32	8
62	16	45	32	8
63	16	45	32	8
64	16	45	32	8
65	16	45	32	8
66	16	45	32	8
67	16	45	32	11
68	16	45	32	11
69	16	45	32	11
70	16	45	32	11
71	16	45	32	11
72	16	45	32	11
73	16	45	32	11
74	16	45	32	11
75	22.6	45	32	11
76	22.6	45	32	11
77	22.6	45	32	11
78	22.6	45	32	11
79	22.6	45	32	11
80	22.6	45	45	16
81	22.6	64	45	16
82	22.6	64	45	16
83	22.6	64	45	16
84	22.6	64	45	16
85	22.6	64	45	16
86	22.6	64	45	16
87	22.6	64	45	16
88	22.6	64	45	16
89	22.6	64	45	16
90	22.6	64	45	16
91	22.6	64	45	16
92	22.6	90	45	16
93	22.6	90	45	22.6
94	22.6	90	64	22.6
95	22.6	90	64	22.6
96	22.6	90	64	22.6
97	32	90	64	22.6
98	32	90	90	32
99	32	90	90	32
100	45	90	90	32

## FORM 4: LATERAL SUSCEPTIBILITY FIELD SHEET

**Circle appropriate nodes/pathway for proposed site  
OR use sequence of questions provided in Form 5.**



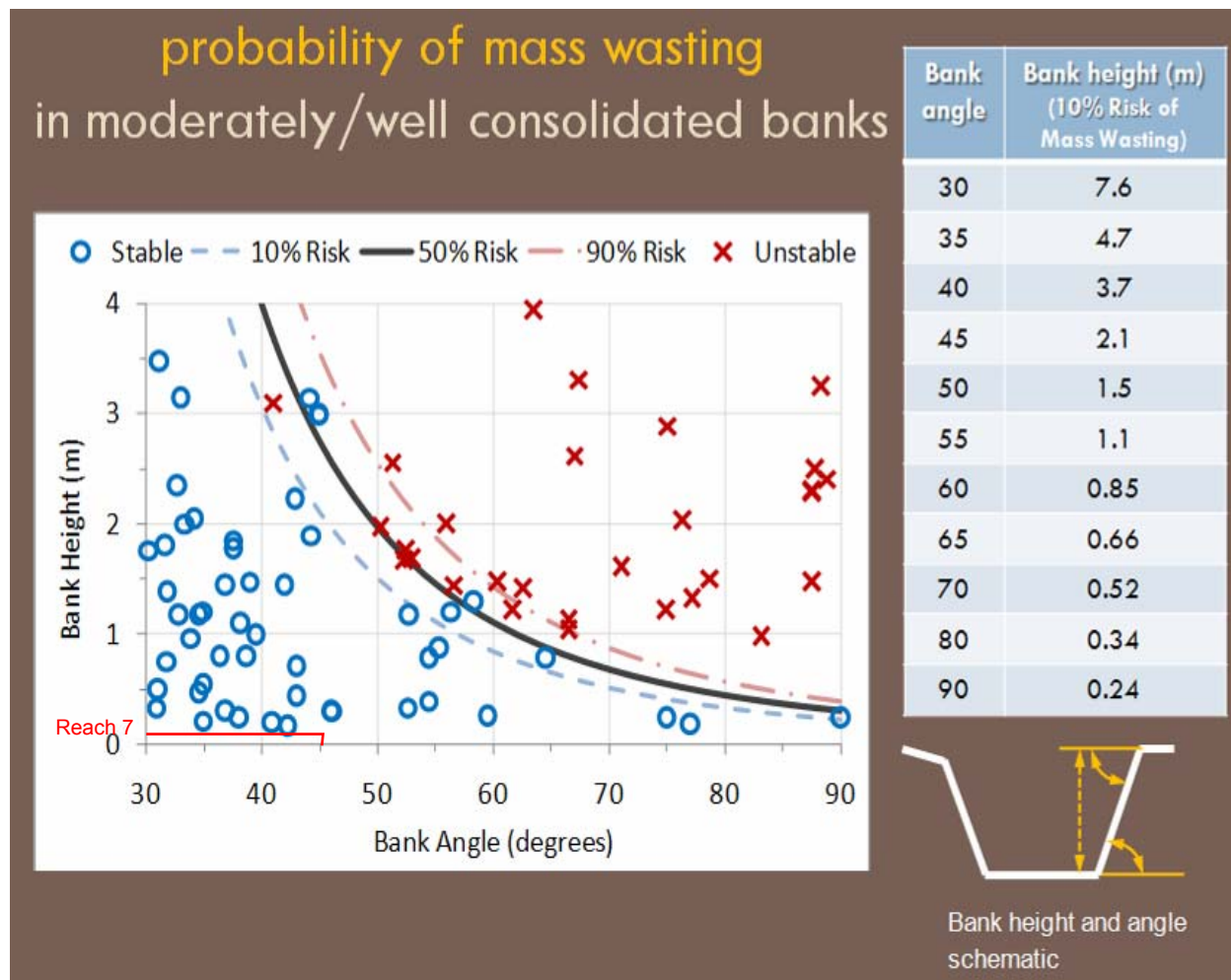
(Sheet 1 of 1)

**This sheet applies to Reaches 1 through 9**

## FORM 6: PROBABILITY OF MASS WASTING BANK FAILURE

If mass wasting is not currently extensive and the banks are moderately- to well-consolidated, measure bank height and angle at several locations (i.e., at least three locations that capture the range of conditions present in the study reach) to estimate representative values for the reach. Use Form 6 Figure 1 below to determine if risk of bank failure is >10% and complete Form 6 Table 1. Support your results with photographs that include a protractor/rod/tape/person for scale.

	Bank Angle (degrees) (from Field)	Bank Height (m) (from Field)	Corresponding Bank Height for 10% Risk of Mass Wasting (m) (from Form 6 Figure 1 below)	Bank Failure Risk (<10% Risk) (>10% Risk)
Left Bank				
Right Bank				



Form 6 Figure 1. Probability Mass Wasting diagram, Bank Angle:Height/% Risk table, and Bank Height:Angle schematic.

(Sheet 1 of 1)

Probability is less than 10% for the existing bank angles (2:1 = 26.6 degrees) in Reaches 1-6 and 8-9. See attached normal depth analysis for bank height in Reach 7 during 10-year flow of 28 cfs.

## Worksheet for Trapezoidal Channel - Reach 7

### Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

### Input Data

Roughness Coefficient	0.030	
Channel Slope	0.06590	ft/ft
Left Side Slope	1.00	ft/ft (H:V)
Right Side Slope	1.00	ft/ft (H:V)
Bottom Width	8.00	ft
<b>Discharge</b>	<b>28.00</b>	<b>ft³/s</b>

### Results

<b>Normal Depth</b>	<b>0.46</b>	<b>ft</b>
Flow Area	3.92	ft²
Wetted Perimeter	9.31	ft
Hydraulic Radius	0.42	ft
Top Width	8.93	ft
Critical Depth	0.70	ft
Critical Slope	0.01640	ft/ft
Velocity	7.14	ft/s
Velocity Head	0.79	ft
Specific Energy	1.26	ft
Froude Number	1.90	
Flow Type	Supercritical	

### GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

### GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.46	ft
Critical Depth	0.70	ft
Channel Slope	0.06590	ft/ft

CRITICAL STRESS CALCULATOR - REACH 5



Define Drainage Basins

Basin: Quarry Creek at Buena Vista Creek

Project: QUARRY CREEK

- Start
- Project
- Basin
- POC
- Export

Manage Your Point of Compliance (POC)

Analyze the receiving water at the 'Point of Compliance' by completing this form. Click Edit and enter the appropriate fields, then click the Update button to calculate the critical flow and low-flow threshold condition. Finally, click Save to commit the changes.

- Cancel
- Save
- Update

Channel Susceptibility: LOW

Low Flow Threshold: 0.5Q2

Channel Assessed: Yes

Watershed Area (ac): 9280.00

Vertical Susceptibility: Low (Vertical)

Lateral Susceptibility: Low (Lateral)

Material: Vegetation

Roughness: 0.100

Channel Top Width (ft): 36.0

Channel Bottom Width (ft): 16.0

Channel Height (ft): 5.0

Channel Slope: 0.008

Large View



CRITICAL STRESS CALCULATOR RESULTS - REACH 6



Define Drainage Basins

Basin: Quarry Creek at Buena Vista Creek

Project: QUARRY CREEK

- Start
- Project
- Basin
- POC
- Export

Manage Your Point of Compliance (POC)

Analyze the receiving water at the 'Point of Compliance' by completing this form. Click Edit and enter the appropriate fields, then click the Update button to calculate the critical flow and low-flow threshold condition. Finally, click Save to commit the changes.

Channel Susceptibility: LOW

Low Flow Threshold: 0.5Q2

- Cancel
- Save
- Update

Channel Assessed: Yes

Watershed Area (ac): 9138.00

Vertical Susceptibility: Low (Vertical)

Lateral Susceptibility: Low (Lateral)

Material: Vegetation

Roughness: 0.100

Channel Top Width (ft): 170.0

Channel Bottom Width (ft): 150.0

Channel Height (ft): 5.0

Channel Slope: 0.001

Large View





Define Drainage Basins

Basin: Quarry Creek at Buena Vista Creek

Project: QUARRY CREEK

- Start
- Project
- Basin
- POC
- Export

Manage Your Point of Compliance (POC)

Analyze the receiving water at the 'Point of Compliance' by completing this form. Click Edit and enter the appropriate fields, then click the Update button to calculate the critical flow and low-flow threshold condition. Finally, click Save to commit the changes.

Cancel

Save

Update

Channel Susceptibility: LOW

Low Flow Threshold: 0.5Q2

Channel Assessed: Yes

Watershed Area (ac): 107.40

Vertical Susceptibility: Low (Vertical)

Lateral Susceptibility: Low (Lateral)

Material: Medium gravel

Roughness: 0.026

Channel Top Width (ft): 16.0

Channel Bottom Width (ft): 8.0

Channel Height (ft): 2.0

Channel Slope: 0.066

Large View





Define Drainage Basins

Basin: Quarry Creek at Buena Vista Creek

Project: QUARRY CREEK

- Start
- Project
- Basin
- POC
- Export

Manage Your Point of Compliance (POC)

Analyze the receiving water at the 'Point of Compliance' by completing this form. Click Edit and enter the appropriate fields, then click the Update button to calculate the critical flow and low-flow threshold condition. Finally, click Save to commit the changes.

- Cancel
- Save
- Update

Channel Susceptibility: LOW

Low Flow Threshold: 0.5Q2

Channel Assessed: Yes

Watershed Area (ac): 307.2

Vertical Susceptibility: Low (Vertical)

Lateral Susceptibility: Low (Lateral)

Material: Vegetation

Roughness: 0.100

Channel Top Width (ft): 80

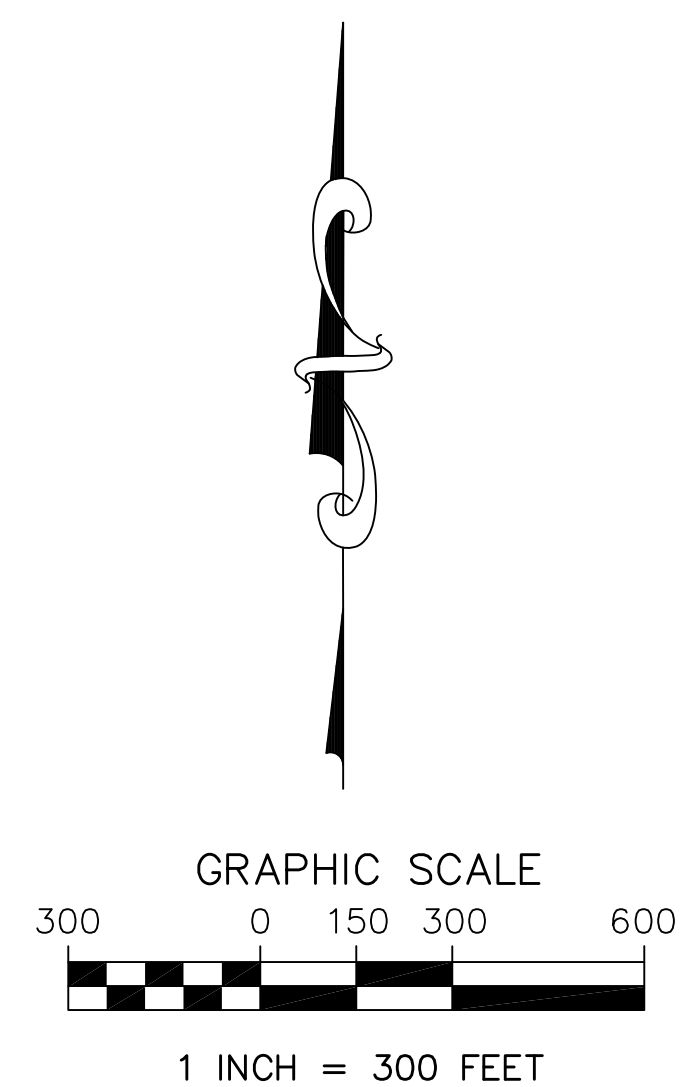
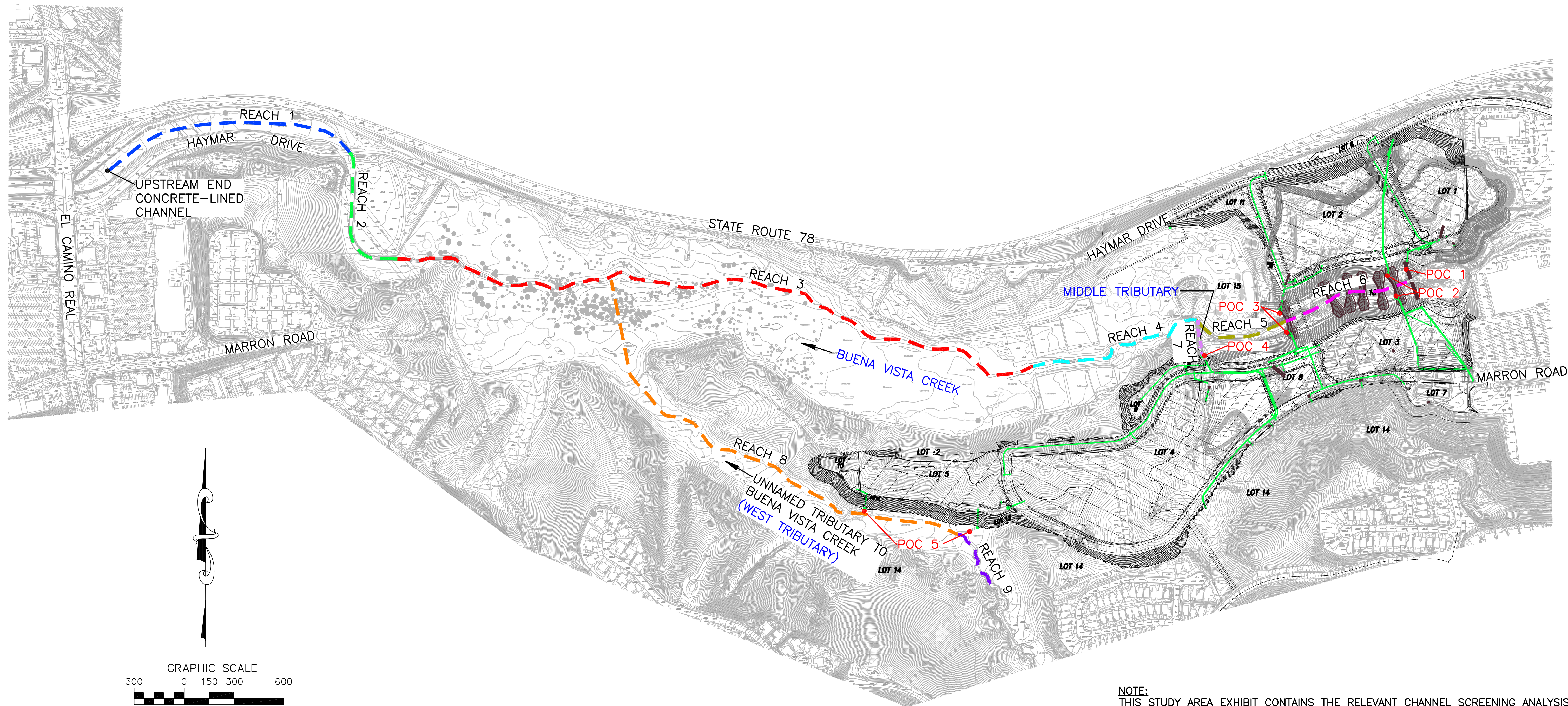
Channel Bottom Width (ft): 60

Channel Height (ft): 5

Channel Slope: 0.016

Large View





**NOTE:**  
 THIS STUDY AREA EXHIBIT CONTAINS THE RELEVANT CHANNEL SCREENING ANALYSIS FEATURES FOR McMILLIN LAND DEVELOPMENT'S QUARRY CREEK PROJECT. THE PROJECT GRADING AND HANSON AGGREGATES' RECLAMATION GRADING/DROP STRUCTURES ARE INCLUDED. THE STORM DRAIN SYSTEMS SERVING THE PROJECT ARE IN GREEN. THE FIVE POINTS OF COMPLIANCE (POC) AT THE STORM DRAIN DISCHARGE LOCATIONS ARE IDENTIFIED. POC'S 1, 2, AND 3 DISCHARGE TO BUENA VISTA CREEK (REACHES 1 THROUGH 6). POC 4 DISCHARGES TO A SMALL NATURAL DRAINAGE CHANNEL (REACH 7 - MIDDLE TRIBUTARY) THAT CONFLUENCES WITH BUENA VISTA CREEK. POC 5 DISCHARGES TO AN UNNAMED NATURAL TRIBUTARY TO BUENA VISTA CREEK (REACHES 8 AND 9 - WEST TRIBUTARY).

## QUARRY CREEK STUDY AREA EXHIBIT